Renewable and Sustainable Energy Reviews 16 (2012) 1157–1164

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Wind energy status in India: A short review

Atul Sharma[a,*], Jaya Srivastava[b], Sanjay Kumar Kar[b], Anil Kumar[c]

[a] Rajiv Gandhi Institute of Petroleum Technology (RGIPT), Rae Bareli 229316, UP, India
[b] Department of Management Studies, Rajiv Gandhi Institute of Petroleum Technology (RGIPT), Rae Bareli 229316, UP, India
[c] Department of Energy, Maulana Azad National Institute of Technology, Bhopal, MP, India

ARTICLE INFO

Article history:
Received 30 March 2011
Received in revised form 8 November 2011
Accepted 9 November 2011
Available online 8 December 2011

Keywords:
Renewable energy
Wind energy
Wind energy generation in India
Wind-farm

ABSTRACT

Renewable energy represents an area of tremendous opportunity for India. Energy is considered a prime agent in the generation of wealth and a significant factor in economic development. Energy is also essential for improving the quality of life. Development of conventional forms of energy for meeting the growing energy needs of society at a reasonable cost is the responsibility of the Government. Limited fossil resources and associated environmental problems have emphasized the need for new sustainable energy supply options. India depends heavily on coal and oil for meeting its energy demand which contributes to smog, acid rain and greenhouse gases' emission. Last 25 years has been a period of intense activities related to research, development, production and distribution of energy in India.

Though major energy sources for electrical power are coal and natural gas, development and promotion of non-conventional sources of energy such as solar, wind and bio-energy, are also getting sustained attention. The use of electricity has grown since it can be used in variety of applications as well as it can be easily transmitted, the uses of renewable energy like wind and solar is rising. Wind energy is a clean, eco-friendly, renewable resource and is nonpolluting. The gross wind power potential is estimated at around 48,561 MW in the country; a capacity of 14,989.89 MW up to 31st August 2011 has so far been added through wind, which places India in the fifth position globally. This paper discusses the ways in which India has already supported the growth of renewable energy technologies i.e. wind energy and its potential to expand their contribution to world growth in a way that is consistent with world's developmental and environmental goals. The paper presents current status, major achievements and future aspects of wind energy in India.

Contents

* Corresponding author. Tel.: +91 535 2704 238; fax: +91 535 2211 888.
E-mail addresses: atul_sharma2@yahoo.com (A. Sharma), jsrivastava@rgipt.ac.in (J. Srivastava), skar@rgipt.ac.in (S.K. Kar), anilkumar76@gmail.com (A. Kumar).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2011.11.018

1. Introduction

In the old economy, energy was produced by burning hydrocarbons-oil, coal, or natural gas-leading to the carbon emissions that have come to define our economy. The world today is facing a major environmental crisis. Global warming, erratic weather patterns, rising fossil fuel prices, oil insecurity and concerns about climate change have cast a shadow over the future of coal, oil and other conventional sources of energy. As a result a new energy economy is emerging. This new economy harnesses the energy in wind, the energy coming from the sun, and heat from within the earth itself. Fossil fuel energies exhaust natural resources and are mostly responsible for adverse environmental impacts leading to climate change. On the other hand, renewable energies in general, and wind energy in particular, produce significantly lower environmental impacts than conventional energies.

India is blessed with plenty of alternate energy sources such as solar, wind, hydro and biomass. India occupies the fifth position in the world, after China, U.S., Germany and Spain in generation of wind power. India is perceived as a developing country, but it is developing at a pace that is not matched by many others. Although we have seen an impressive increase in installed capacity addition, from barely about 1350 MW at the time of independence (1947) to about 160,000 MW today, over 90,000 MW of new generation capacity is required in the next seven years. The importance of renewable energy was recognized in the country in the early 1970s. India has today many large programmes for renewable energy. Several renewable energy systems and devices are now commercially available. The development of wind power in India began in the 1990s, and has significantly increased in the last few years.

Indian government policy framework in wind energy generation is extremely investor-friendly, and an attractive tariff and regulatory regime provide a strong foundation for the growth of the sector. Ministry of New and Renewable Energy has recently taken the decision to introduce generation-based incentives, a scheme whereby investors will receive a financial incentive per unit of electricity generated over ten years. The decision to incentivize the generation of power will create a level playing field between foreign and domestic investors, and hopefully this will catalyze more investments in this field by large independent power producers and foreign investors.

2. Worldwide status of wind energy

Wind is the centerpiece of the energy economy. It is abundant, low cost, and widely distributed; it scales up easily and can be developed quickly. Oil wells go dry and coal seams run out, but the earth's wind resources cannot be depleted.

China overtook U.S. as the world leader in wind power in 2010, according to a new annual report by the Global Wind Energy Council. Over the past decade, China's installed wind capacity has grown exponentially, from just 300 MW in 2000 to 42,287 MW last year, and now accounts for 21.8% of the world's total wind power capacity. In 2010 China installed more turbines than U.S. while U.S. wind industry built 5115 MW of wind power last year, which was about half of 2009's record pace, according to the American Wind Energy Association (AWEA). However, AWEA said U.S. industry entered 2011 with more than 5600 MW under construction [1].

Global capacity of wind power installations grew by 35,652 MW in 2010, a 22.46% increase on the 158,738 MW installed at the end of 2009 [2]. This brings total installed wind energy capacity up to 194,390 MW. China (42,287 MW), U.S. (40,180 MW), Germany (27,214 MW), Spain (20,676 MW) are ahead of India (13,065 MW) which is at the fifth position. Table 1 shows the cumulative installed capacity of the top 10 countries. The wind capacity worldwide reached 194,390 MW, after 158,738 MW in 2009, 120,291 MW in 2008, 93,820 MW in 2007, 74,052 MW in 2006, and 59,091 MW in 2005 as shown in Fig. 1 since 1996 to 2010 [3]. For the first time, more than half of all new wind power was added outside of the traditional markets in Europe and North America. The shift was driven mainly by the continuing boom in China, which installed 16,482 MW in 2010 and now claims global leadership with 42,287 MW of wind power. Overall, the annual 2010 wind market was down for the first time in 20 years, shrinking by 7.27% from 38,610 MW in 2009, due largely to slowdowns in the U.S. and Europe.

3. Wind energy potential in India

The total potential for wind power in India was first estimated by the Centre for Wind Energy Technology (C-WET) at around 45 GW, and was recently increased to 49.13 GW [4]. This was adopted by the government as the official estimate. The C-WET study was based on a comprehensive wind mapping exercise initiated by MNRE, which established a country-wide network of 1050 wind monitoring and wind mapping stations in 25 Indian States. The assessment shows that India's total wind potential is 48,561 MW, with Karnataka, Gujarat, and Andhra Pradesh as the leading states up to 31st August 2011 [4,5]. This effort made it possible to assess the national wind potential and identify suitable areas for harnessing wind power for commercial use, and 216 suitable sites have been identified. Table 2 shows the wind energy potential and installation up to 31st August 2011 within India. However, the wind measurements were carried out at lower hub heights and did not take into account technological innovation and improvements and repowering of old turbines to replace them with bigger ones. At heights of 55–65 m, the Indian Wind Turbine Manufacturers Association (IWTMA) estimates that the potential for wind development in

Table 1
Top 10 cumulative installed capacity 2009–2010 [2,3].

Rank	Country	MW (2009)	MW (2010)	% (2010)
1	PR China	25,805	42,287	21.8
2	US	35,086	40,180	20.7
3	Germany	25,777	27,214	14.0
4	Spain	19,160	20,676	10.6
5	India	10,926	13,065	6.7
6	Italy	4849	5797	3.0
7	France	4574	5660	2.9
8	UK	4245	5204	2.7
9	Denmark[a]/Canada[b]	3465	4009	2.1
10	Portugal[a]/Denmark[b]	3357	3752	1.9
	Rest of world	21,494	26,546	13.7
	Total top 10	137,244	1,67,844	86.3
	World total	158,738	1,94,390	100

[a] Rank in 2009 year.
[b] Rank in 2010 year.

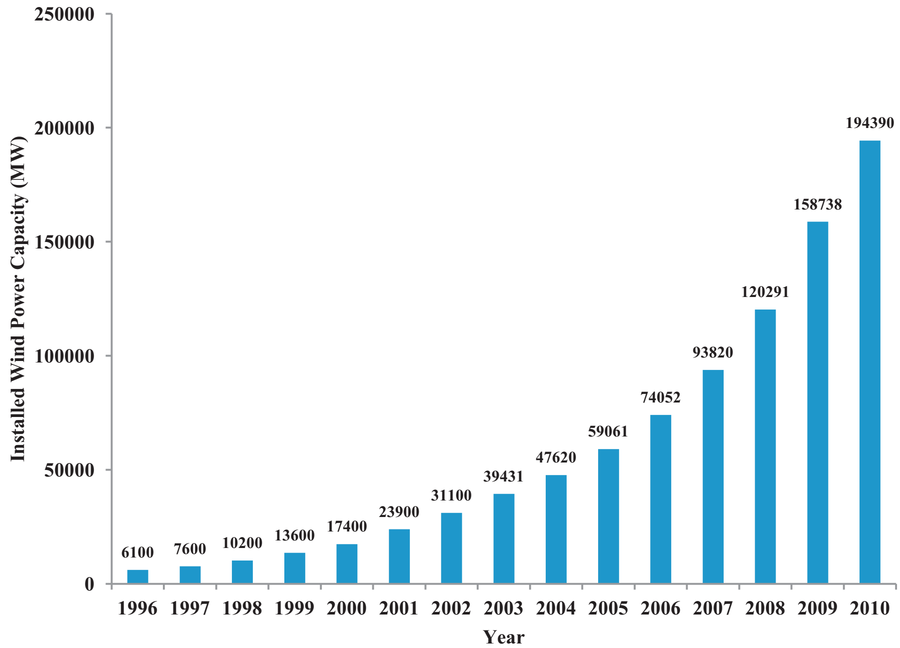


Fig. 1. Global cumulative installed wind capacity 1996–2010.

India is around 65–70 GW [6]. The World Institute for Sustainable Energy, India (WISE) considers that with larger turbines, greater land availability and expanded resource exploration, the potential could be as big as 100 GW.

4. Wind energy programme in India

Energy 'self-sufficiency' was identified as the major driver for new and renewable energy in the country in the wake of the two oil shocks of the 1970s. The sudden increase in the price of oil, uncertainties associated with its supply and the adverse impact on the balance of payments position led to the establishment of the Commission for Additional Sources of Energy (CASE) in the Department of Science & Technology in March 1981. The Commission was charged with the responsibility of formulating policies and their implementation, programmes for development of new and renewable energy apart from coordinating and intensifying R&D in the sector. In 1982, a new department, i.e. Department of Non-conventional Energy Sources (DNES), that incorporated CASE, was created in the then Ministry of Energy. In 1992, DNES became the Ministry of Non-conventional Energy Sources (MNES), the world's first ministry committed to renewable energy. In October 2006, the Ministry was re-christened as the Ministry of New and Renewable Energy (MNRE) [7].

Table 2
Wind energy potential in India according to C-WET [4,5].

State	Gross potential (MW)	Total capacity (MW) till 31.08.11
Tamil Nadu	5530	6286.02
Maharashtra	4584	2400.05
Gujarat	10,645	2337.31
Karnataka	11,531	1773.25
Rajasthan	4858	1678.62
Madhya Pradesh	1019	275.89
Andhra Pradesh	8968	199.15
Kerala	1171	35.30
West Bengal	–	1.1
Orissa	255	–
Others		3.2
Total	48,561	14,989.89

India has been a pioneer in the commercial use of wind energy in Asia. The development of wind power in India began in the 1990s, and has progressed steadily in the last few years. MNRE is dedicated to expanding contributions of renewable energy in all of India's end-use sectors and undertakes policy and planning activities to that end. MNRE also supervises national-level renewable energy institutes such as the Solar Energy Centre and the Centre for Wind Energy Technology. The Indian Renewable Energy Development Agency (IREDA) provides financial support and innovative financing for renewable energy and energy efficiency projects with funds from the Indian government and multilateral lending agencies. IREDA also administers the central government's renewable energy incentive programs. Other government institutions with direct responsibilities that extend into renewable energy include several units under the Ministry of Power, the Planning Commission, and the Prime Minister's Council on Climate Change [7,8]. The short gestation periods for installing wind turbines, and the increasing reliability and performance of wind energy machines have made wind power a favored choice for capacity addition in India. It is estimated that 6000 MW of additional wind power capacity will be installed in India between 2010 and 2012, taking the total installed capacity beyond 15,000 MW [9,10].

National Aeronautical Laboratory (NAL) was among first which developed a 4.9 m diameter conventional multi-vane wind mill in mid 1960s thereafter sail-type windmills under a project initiated by NAL during 1976–1977. The Wind Power Programme in India was initiated towards the end of the Sixth Plan, in 1983–84. The programme aims at survey and assessment of wind resources, setting up demonstration projects, and provision of incentives to make wind electricity competitive. The programme is being implemented through the State Nodal Agencies, Field Research Unit of Indian Institute of Tropical Meteorology (IITM-FRU) and Center for Wind Energy Technology (C-WET). The IWTMA has played a leading role in promoting wind energy in India.

Currently, India has over 21,125.38 MW of installed renewable power generating capacity [11]. Installed wind capacity is the largest share at over 14,989.89 MW, followed by small hydro

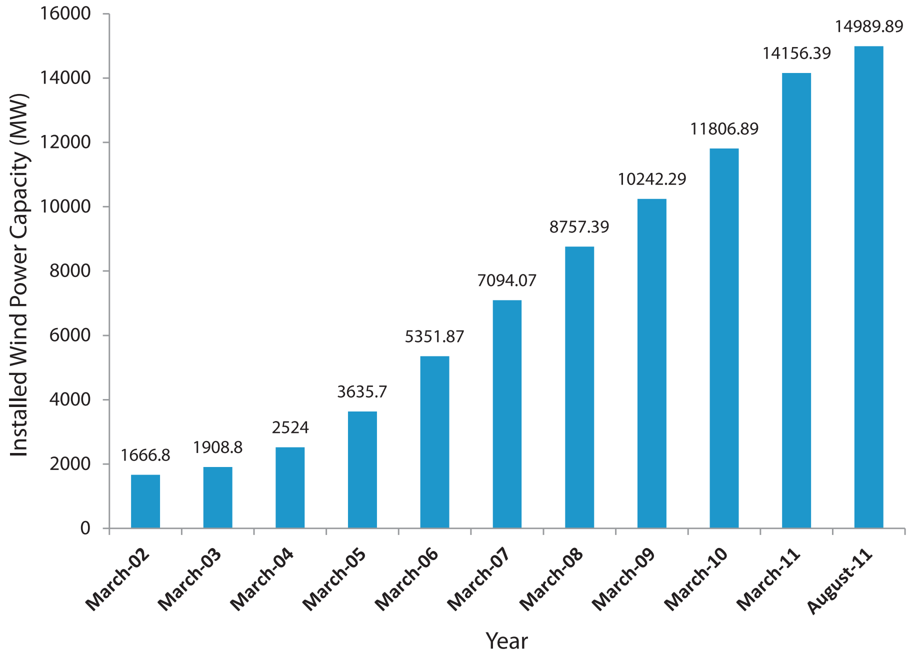


Fig. 2. Wind power growth in India (MW).

projects at 3153 MW. The Eleventh Plan calls for grid-connected renewable energy to exceed 25 GW by 2012. During the last financial year i.e. 1st April 2010 to 31st March 2011, India added 2349.50 MW of wind capacity for a total installed capacity of 14,156.39 MW, which is represented a 19.90% annual growth rate. The most recent data available at the time of writing this paper shows that India's wind capacity totalled 14,989.89 MW at the end of 31st August 2011, which represented 70.96% of India's total renewable energy capacity. India's robust domestic market has transformed the Indian wind industry into a significant global player. Fig. 2 is showing the year wise installation of wind energy since 1999 to August 2011.

5. Wind energy status in India

India's rapidly growing economy and population leads to relentlessly increasing electricity demand. The IEA predicts that by 2020, 327 GW of power generation capacity will be needed, which would imply an addition of 16 GW per year. This urgent need is reflected in the target the Indian government has set in its 11th Five Year Plan (2007–2012), which envisages an addition of 78.7 GW in this period, 50.5 GW of which is coal [12].

With an installed capacity of 21,125.38 MW, renewable energy sources (excluding large hydro) currently account for 6% of India's overall power generation capacity. By 2012, the Indian government is planning to add an extra 14 GW of renewable sources. In its 10th Five Year Plan, the Indian government had set itself a target of adding 3.5 GW of renewable energy sources to the power generation mix. In reality, however, nearly double that figure was achieved. In this period, more than 5.4 GW of wind energy was added to the generation mix, as well as 1.3 GW from other renewable energy sources. The target set for the period from 2008 to 2012 was increased to 14 GW, 10.5 GW of which is to be new wind generation capacity. The MNRE estimates that there is a potential of around 90,000 MW for power generation from different renewable energy sources in the country, including 48,561 MW of wind power, 14,294 MW of small hydro power and 26,367 MW of biomass [13].

The potential areas for generating power through wind mills are in the states of Tamil Nadu, Karnataka, Kerala, Gujarat, Andhra Pradesh, Kerala, Maharashtra, Rajasthan and Madhya Pradesh. As of 31st August 2011 the installed capacity of wind power in India was 14,989.89 MW mainly spread across Tamil Nadu (6286.02 MW), Maharashtra (2400.05 MW), Gujarat (2337.31 MW), Karnataka (1773.25 MW), Rajasthan (1678.62 MW), Madhya Pradesh (275.89 MW), Andhra Pradesh (199.15 MW), Kerala (35.30 MW), West Bengal (1.1 MW) as shown in Table 2 also. Table 3 shows the year wise installation of wind power in India since March 2005 to 31st August 2011, while Table 4 shows the

Table 3
Year wise installed capacity in India [14,15].

State	Up to March 02	March 03	March 04	March 05	March 06	March 07	March 08	March 09	March 10	March 11	Up to 31st August 11
Andhra Pradesh	93.20	93.20	99.40	121.20	121.65	122.45	122.45	122.45	136.05	191.45	199.15
Gujarat	181.40	187.60	216.50	268.00	352.60	636.55	1252.91	1566.51	1863.61	2176.41	2337.31
Karnataka	69.30	124.90	209.80	411.30	555.10	821.05	1011.35	1327.35	1472.75	1726.85	1773.25
Kerala	2.00	2.00	2.00	2.00	2.00	2.00	10.50	27.00	27.80	35.30	35.30
Maharashtra	400.30	402.30	408.50	457.30	1002.40	1487.70	1755.85	1938.85	2077.75	2316.85	2400.05
Madhya Pradesh	23.20	23.20	23.20	29.50	40.90	57.30	187.69	212.79	229.39	275.89	275.89
Rajasthan	16.10	60.70	178.50	284.80	358.07	469.97	538.92	738.52	1088.52	1525.22	1678.62
Tamil Nadu	877.00	1010.60	1381.80	2057.30	2914.85	3492.75	3873.42	4304.52	4906.72	5904.12	6286.02
West Bengal	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Others	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Total	1666.80	1908.80	2524.00	3635.70	5351.87	7094.07	8757.39	10,242.29	11,806.89	14,156.39	14,989.89

Table 4
Year wise capacity addition in India [14,15].

State	Year-wise installed capacity addition (MW)											Total
	Up to Mar.02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	[a]-11	Capacity (MW)
Andhra Pradesh	93.2	0	6.2	21.8	0.45	0.8	0	0	13.6	55.4	7.7	199.15
Gujarat	181.4	6.2	28.9	51.5	84.6	283.95	616.36	313.6	297.1	312.8	160.9	2337.31
Karnataka	69.3	55.6	84.9	201.5	143.8	265.95	190.3	316	145.4	254.1	46.4	1773.25
Kerala	2	0	0	0	0	0	8.5	16.5	0.8	7.5	0	35.3
Maharashtra	400.3	2	6.2	48.8	545.1	485.3	268.15	183	138.9	239.1	83.2	2400.05
Madhya Pradesh	23.2	0	0	6.3	11.4	16.4	130.39	25.1	16.6	46.5	0	275.89
Rajasthan	16.1	44.6	117.8	106.3	73.27	111.9	68.95	199.6	350	436.7	153.4	1678.62
Tamil Nadu	877	133.6	371.2	675.5	857.55	577.9	380.67	431.1	602.2	997.4	381.9	6286.02
West Bengal	1.1	0	0	0	0	0	0	0	0	0	0	1.1
Others	3.2	0	0	0	0	0	0	0	0	0	0	3.2
Total (MW)	1666.8	242	615.2	1111.7	1716.17	1742.2	1663.32	1484.9	1564.6	2349.5	833.5	14,989.89

[a] 1st April 2011 to 31st August 11.

year wise capacity addition in India within the financial year i.e. 1st April to 31st March with the current year installation up to 31st August 2011 [14,15].

6. Steady market growth for wind

Wind energy is continuing to grow steadily in India. India's capacity additions of more than 5000 MW between 2007 and 2010 are shown statewise in Table 2. The states with highest wind power concentration are Tamil Nadu, Maharashtra, Gujarat, Rajasthan, Karnataka, Madhya Pradesh and Andhra Pradesh. While, the largest gains were seen in Tamil Nadu and Gujarat only. Tamil Nadu in south India has set itself apart from the other states with a total installed capacity of 6286.02 MW, or 41.94% of India's total installed capacity, as of 31st August 2011. This is beginning to change as other states, including Maharashtra, Gujarat, Rajasthan and Karnataka, West Bengal, Madhya Pradesh and Andhra Pradesh start to catch up, partly driven by new policy measures. As a result, wind farms can be seen under construction all across the country, from the coastal plains to the hilly hinterland and sandy deserts. The Indian government envisages the addition of 2 GW/annum in the next five years. Wind power capacity of 13,912.89 MW was added in the last twelve years, taking the total installed capacity to 14,989.89 MW on 31st August 2011, up from 1077 MW at the end of 1999. This represents 70.96% of India's total renewable energy capacity [7,11].

"Indian Wind Energy Outlook 2009" published in September 2009 in by the Global Wind Energy Council (GWEC) and IWTMA [16] examined the potential of wind power in India up to the year 2030 and found that the technology, re-powering, untapped off-shore potential and furthering wind resource assessment could play a key part in the nation's effort to provide energy to its ever growing demand in an economy which will boom and at the same time combat climate change. The report explains how wind energy can provide up to 24% of the India's power needs by 2030 while attracting $10637.12 million in investment every year and creating 213,000 'green collar' jobs in manufacturing, project development, installation, operation, maintenance, consulting etc. At the same time, it would save a total of 5.5 bn tons of CO_2 in that timeframe and would generate 5.5 bn carbon credits amounting to $80 bn. Wind energy, as a power generation technology, greatly aids in offsetting carbon (CO_2) emissions from burning of fossil fuel for generating electricity.

7. Indian wind energy policy

In keeping with its aim of having a holistic, sustainable energy policy the government of India is encouraging investment in non-conventional energy sources. In the 11th Plan the government has proposed a financial outlay of $44.79 million on R&D in wind energy sector. The government does not want to focus its energies on actually setting up wind power projects. Instead it wants to concentrate only on R&D, developing small projects in remote areas and setting up demonstration projects.

Wind energy power projects are capital intensive and hence investors have to be provided continuous support. The average pay back period for wind power projects is 25 years. However the bright side to this scenario is that unlike other sectors technology changes very slowly in this area, hence manufacturers do not have to worry about technological obsolence.

Keeping all these considerations in mind the government has formulated a strategy of providing incentives to private manufacturers in this sector. The Indian Government is giving income tax holidays, concessional custom duty/duty free import and accelerated depreciation, to investors in this field. The various State Governments are providing support in the form of energy buy back, power wheeling and banking facilities, sales tax concession benefits, electricity tax exemption and capital subsidy.

The government has also come up with a Generation Based Incentive (GBI) Scheme. The features of the scheme are as follows [17]:

1. The GBI Scheme is applicable only for those power producers who do not avail of the accelerated depreciation benefits under the Income Tax Act.
2. All grid integrated projects of capacity of more than 5 MW are eligible for this scheme. The project has to be synchronized with the grid and certified by the utility.
3. Wind site has to be validated by C-WET.
4. Electricity generated from the project should be sold to the grid.
5. The MNRE will provide the GBI of Rs. 0.50 per unit for a period of ten years to the eligible project promoters through IREDA. This scheme is currently valid for wind farms installed before 31 March 2012. This incentive shall be in addition to the tariff determined by the State Electricity Regulatory Commission (SERC).
6. The IREDA will disburse the generation based incentive to the generator on half yearly basis through e-payment.
7. Not applicable for those who have set up capacities for captive consumption, third party sale, merchant plants.
8. The component of the scheme will be reviewed when projects aggregating to 49 MW which are estimated to generate around 0.9 billion units of electricity will get registered by IREDA.

The scheme will be reviewed in the last year of the 11th Plan and if the response is good this scheme can be further upgraded. The SERCs in Andhra Pradesh, Gujarat, Haryana, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, and West Bengal have announced preferential tariff for purchase of power from

Table 5
India's largest wind power facilities (10 MW and greater) [15].

Power plant	Owner	Location		Total capacity (MWe)
		City	State	
Vankusawade Wind Park	Suzlon Energy Ltd.	Satara Dist.	Maharashtra	259
Cape Comorim	Aban Lloyd Chiles Offshore Ltd.	Cape Comorim	Tamil Nadu	33
Kayathar Subhash	Subhash Ltd.	Kayathar	Tamil Nadu	30
Ramakkalmedu	Subhash Ltd.	Ramakkalmedu	Kerala	25
Muppandal Wind	Muppandal Wind Farm	Muppandal	Tamil Nadu	22
Gujdimangalam	Gujdimangalam Wind Farm	Gujdimangalam	Tamil Nadu	21
Puthlur RCI	Wescare (India) Ltd.	Puthlur	Andhra Pradesh	20
Lamda Danida	Danida India Ltd.	Lamda	Gujarat	15
Chennai Mohan	Mohan Breweries & Distilleries Ltd.	Chennai	Tamil Nadu	15
Jamgudrani MP	MP Windfarms Ltd.	Dewas	Madhya Pradesh	14
Jogmatti BSES	BSES Ltd.	Chitradurga Dist.	Karnataka	14
Perungudi Newam	Newam Power Company Ltd.	Perungudi	Tamil Nadu	12
Kethanur Wind Farm	Kethanur Wind Farm	Kethanur	Tamil Nadu	11
Hyderabad APSRTC	Andhra Pradesh State Rapid Transit Corp.	Hyderabad	Andhra Pradesh	10
Muppandal Madras	Madras Cements Ltd.	Muppandal	Tamil Nadu	10
Poolavadi Chettinad	Chettinad Cement Corp. Ltd.	Poolavadi	Tamil Nadu	10

wind power projects. Many States have also announced renewable energy purchase obligations, which catalyses the growth in the wind power generation. The Rajasthan State Electricity Regulatory Commission (RERC) issued the modified tariff policy for renewables during the year. As per this policy, a tariff of Rs. 4.28 per unit for Jaisalmer, Jodhpur and Barmer districts and tariff of Rs. 4.50 per unit for other districts is available. The Tamil Nadu Electricity Regulatory Commission also announced the modified tariff rate during the year for wind power projects. The new rates are Rs. 3.39 per unit [18].

8. State-level wind power growth

There are growing wind energy installations in a number of states across India. Overall 214 wind farm has been installed in India [19]. Table 5 shows India's largest wind power facilities.

8.1. Tamil Nadu (6286.02 MW)

Tamil Nadu has shown remarkable progress in the field of wind energy utilizing almost full wind power potential with 41.94% of India's total wind installations. With the right mix of policies, Tamil Nadu has also become the hub of wind energy manufacturing with global heavyweights like Suzlon, Gamesa, Vestas all building plants in the State. A number of new players like Sterling Infotech and Lietner have also started manufacturing Wind Turbines in Tamil Nadu due to favorable networking effects. Tamil Nadu is the state with most wind generating capacity: 6286.02 MW at the end of August 2011 [4].

Not far from Aralvaimozhi, the Muppandal wind farm which the largest in Asia is located near Muppandal, supplying the villagers with electricity for work. The village had been selected as the showcase for India's $2 billion clean energy program which provides foreign companies with tax breaks for establishing fields of wind turbines in the area. In February 2009, Shriram EPC bagged $15.68 million contracts for setting up of 60 units of 250 kW (15 MW) wind turbines in Tirunelveli district by Cape Energy. In Tamil Nadu, Coimbatore and Tiruppur Districts having more wind Mills from 2002 onwards, specially, Chittipalayam, Kethanoor, Gudimangalam, Poolavadi, Murungappatti are the high wind power production places in both districts.

8.2. Maharashtra (2400.05 MW)

The Maharashtra government is considering having Special Economic Zones (SEZs) for wind energy farms where players from the segment will be encouraged to set up projects and supply power to the grid. The state has already decided to have a single window system for land acquisition process for the purpose and is working on an incentive package to make it attractive to establish wind energy projects across a vast land mass. Maharashtra is second only to Tamil Nadu in terms of generating capacity [4]. In 2006–07, Gujarat Fluorochemicals Ltd. commissioned a 23.1 MW wind power project at Gudhe village near Panchgani in Satara district of Maharashtra.

8.3. Gujarat (2337.31 MW)

The Gujarat government, which is banking heavily on wind power, has identified Samana as an ideal location for installation of 450 turbines that can generate a total of 360 MW. To encourage investment in wind energy development in the state, the government has introduced a draft of incentives including a higher wind energy tariff. Samana has a high tension transmission grid and electricity generated by wind turbines can be fed into it. For this purpose, a substation at Sadodar has been installed. Both projects are being executed by Enercon Ltd., a joint venture between Enercon of Germany and Mumbai-based Mehra group.

Companies like China Light Power (CLP) and Tata Power have pledged to invest up to Rs. 8.15 billion in different projects in Samana in Rajkot district. CLP, through its India subsidiary CLP India, is investing close to $111.6 million for installing 126 wind turbines in Samana that will generate 100.8 MW power. Tata Power has installed wind turbines in the same area for generating 50 MW power at a cost of $70.3 million. Both projects are expected to become operational by early next year, according to government sources. ONGC Ltd. has commissioned its first wind power project in Gujarat. The 51 MW project is located at Motisindholi in Kutch district of Gujarat. ONGC had placed the EPC order on Suzlon Energy in January 2008, for setting up the wind farm comprising 34 turbines of 1.5 MW each. Work on the project had begun in February 2008, and the first three turbines had begun production within 43 days of starting construction work. Power from this $68.73 million captive wind farm will be wheeled to the Gujarat state grid for onward use by ONGC at its Ankleshwar, Ahmedabad, Mehsana and Vadodara centres. ONGC has targeted to develop a captive wind power capacity of around 200 MW in the next two years.

8.4. Karnataka (1773.25 MW)

There are many small wind farms in Karnataka, making it one of the states in India which has a high number of wind mill farms. The state has the potential of generating 11,531 MW from wind energy,

while 1773.25 MW has been installed up to 31st August, 2011. Wind power projects are proposed at the few more disticts i.e. Kappatagudda (Dharwad), Jogimatti (Chitradurga), Gokak (Belgaum District), Malagatti, Hanumasagar (Raichur District), Bommanahall and Hanumanamatti (Dharwad District) [20].

Chitradurga, Gadag are some of the districts where there are a large number of Windmills. Chitradurga alone has over 20,000 wind turbines. The 13.2 MW Arasinagundi and 16.5 MW Anaburu wind farms are ACCIONA's [21] first in India. Operations at the Anabaru wind farm (16.5 MW) commenced with 10 wind turbines of 1.65 MW per unit. In 2007, ACCIONA installed the Arasinagundi wind farm, 13.2 MW, located in the Davangere district (Karnataka State), they have a total installed capacity of 29.7 MW and comprise a total 18 Vestas 1.65 MW wind turbines supplied by Vestas Wind Technology India Pvt. Ltd. Each facility has signed a 20-year Power Purchase Agreement (PPA) with Bangalore Electricity Supply Company for off-take of 100% of the output. Their renewable energy production over the 10-year period stipulated will avoid the emission of 882,400 tons of CO_2 that would have been generated to produce the same volume of electricity from power generation plants in Karnataka in that period of time. The company that owns the wind farms will obtain Certifications of Emissions Reductions (CERs) that it could then sell in the emissions trading market. ACCIONA Energy has also started construction work on its third wind park Tuppadahalli (56.1 MW) in India, which will come on stream in 2011. The new park will contain thirty-four 1.65 MW wind. Representing an investment of $82 million, the wind park will strengthen the company's presence in India and increase its wind power capacity in the country to 85.8 MW.

8.5. Rajasthan (1678.62 MW)

Rajasthan is emerging as an important destination for new wind farms; it is currently in the top five states in terms of installed capacity. Gurgaon-headquartered Gujarat Fluorochemicals Ltd. is in an advanced stage of commissioning a large wind farm in Jodhpur district of Rajasthan. In an independent development, cement major ACC Ltd. has proposed to set up a new wind power project in Rajasthan with a capacity of around 11 MW. Expected to cost around $13.44 million, the wind farm will meet the power requirements of the company's Lakheri cement unit. As a part of its wind power foray, the company has plans to invest $1338.8 million over the next five years and is targeting to produce nearly 1000 MW of wind energy.

8.6. Madhya Pradesh (275.89 MW)

The state has the potential of generating 1019 MW from wind energy, while 275.89 MW has been installed up to 31st August, 2011. Present Rs. 3.97 p/kWh is coming down to Rs. 3.30 from the 5th year to 20th year. Through first 15 MW Wind Power Estate developed near Dewas in Madhya Pradesh, M.P Windfarms Ltd. has ensured hassle-free implementation as also most efficient operation and maintenance services to 15 different investors from all over the country. In consideration of its unique concept, Govt. of Madhya Pradesh sanctioned another 15 MW project to MPWL at Nagda Hills near Dewas. All the 25 Wind Electric Generators (WEGs) have been commissioned on 31.03.2008 and are under successful operation [22].

Nakoda, a polyester filament yarn firm, has announced plans to commence a wind energy project in Madhya Pradesh by March 2011. The company plans to make an investment of $7.4 million on this project. The plant will be built at Jethana in the district of Ratlam. The plant will comprise seven turbines with 750 kW capacities each, totalling to 5.25 MW capacities. Once the new machines are commissioned, the wind energy capacity of Nakoda will increase to 12 MW capacities from its existing 6.75 MW capacity. Nakoda intends to purchase wind mills from a Reliance ADAG Group-floated company Global Wind Power (GWPL). These wind turbines are produced by GWPL in partnership with Norwin Denmark. Nakoda will establish a power purchase contract with Madhya Pradesh Electricity Board for supplying 112 lakh units of electricity annually for a period of 13 years [23].

8.7. Andra Pradesh (199.15 MW)

Based on the studies conducted through wind monitoring exercise, it is found that the southern part of Andhra Pradesh has got wind potential for setting up of wind farms. The areas in Anantapur, Cuddapah, Kurnool and parts of Nellore and Chittoor district have relatively better potential sites to set up wind power projects. Non Conventional Energy Development Corporation of Andhra Pradesh Ltd. (NEDCAP) has established 2.25 MW wind farm project at Kondamedapally, Kurnool district and 2.50 MW wind farm at Narasimhakonda, Nellore district under demonstration scheme of MNRE with a view to encourage investment and to promote wind power projects in Andhra Pradesh. NEDCAP is the single window clearance agency to sanction projects up to 20 MW capacities in the State and so far 100.12 MW capacities of projects by 30 developers at Ramagiri, Kadavakallu, Tallimadugula in Anantapur District and on Tirumala Hills, Chittoor district, have been commissioned. The total installed capacity in A.P. is 199.15 MW as on 31st August, 2011 [24].

A wind power project is also installed in Kadavakallu of Ananthpur District in Andhra Pradesh, India promoted by M/s Hyderabad Chemicals Limited. This project activity generates 4.5 MW from 6 wind mills of capacity 750 MW each [25].

8.8. Kerala (35.30 MW)

The Agency for Non-Conventional Energy and Rural Technology (ANERT), an autonomous body under the Department of Power, Government of Kerala, is setting up wind farms on private land in various parts of the state to generate a total of 600 MW of power. The agency has identified 16 sites for setting up wind farms through private developers. To start with, ANERT will establish a demonstration project to generate 2 MW of power at Ramakkalmedu in Idukki district in association with the Kerala State Electricity Board. Other wind farm sites include Palakkad and Thiruvananthapuram districts. 20 MW wind energy generators also have been installed in Kerala (Idukky, Plakkad district) with active private participation. It is expected that another 30 MW would be installed during the end of this year [26].

The first wind farm of the state was set up at Kanjikode in Palakkad district. It has a generating capacity of 23.00 MW. A new 10.5 MW wind farm project was launched with private participation at Ramakkalmedu in Idukki district [27].

8.9. West Bengal (1.10 MW)

West Bengal is implementing one of the largest programmes on Renewable Energy in India covering a broad spectrum of energy technologies like Solar Thermal, Solar Photovoltaic, Wind Turbines, Improved Chulhas, Biogas Plants, Biomass Gasifier, Small Hydro and Tidal Power etc. These activities are, mainly, taking place in areas where it is very difficult, cost prohibitive or almost impossible to supply power through conventional grid [28].

The total installation in West Bengal is just 1.10 MW as there were only 0.5 MW additions in 2006–2007. Suzlon Energy Ltd. is planning to set up a large wind-power project in West Bengal, for which it is looking at coastal Midnapore and South 24-Parganas districts. According to West Bengal Renewable Energy Development

Agency, the 50 MW project would supply grid-quality power. This project would be the biggest in West Bengal using wind energy. Suzlon aims to generate the power solely for commercial purpose and sell it to local power distribution outfits like the West Bengal State Electricity Board (WBSEB). Suzlon will invest around $55.8 million initially, without taking recourse to the funding available from the IREDA. Five wind-power units are working in West Bengal, at Frazerganj, generating a total of around 1 MW. At Sagar Island, there is a composite wind-diesel plant generating 1 MW. In West Bengal, power companies are being encouraged to buy power generated by units based on renewable energy. The generating units are being offered special rates [29].

9. Conclusions

India's growing energy demand requires efficient energy management. In the coming years energy mix of the country is going to change. There is no doubt that renewable sources of energy would play critical role in ensuring energy security of the country. There is enormous potential to generate energy from renewable sources like solar and wind. The government of India has been very actively involved in promoting renewable energy. It has been observed that the size of wind turbine has increased and the cost of production has decreased. The cost per kW typically varies from around $1413.8/kW to $1908.6/kW. The future challenge is to bring down the cost further and make it more competitive. The wind turbine cost contributes 68–84% total cost. Hence, it is important to design, develop and market newer, technologically superior and more cost efficient wind turbines to reduce unit cost of wind power. It is high time for the government to develop a comprehensive renewable energy policy and design support schemes to send across positive signals to the wind power producers. These producers should be encouraged to invest in wind energy.

No doubt, India has marked its presence all over the world in generation of wind energy. It has huge potential for producing wind energy too, but there are still some lacunas. Indian government has laid the foundation for a broad-based renewable energy program and designed it specially to meet the growing energy needs, and to fulfil energy shortage. Despite all its efforts, India is unsettled by China and has now slipped to the fifth rank in its contribution to global wind energy production. Analysis shows that the main factor behind China's lead is presence of a countywide renewable energy law. It may be concluded that India will have to improve in order to compete with China and become the leader in wind energy generation.

Acknowledgements

Authors are highly thankful to the Director Prof. J.P. Gupta, Rajiv Gandhi Institute of Petroleum Technology (RGIPT), Rae Bareli for providing support to carry out the work at RGIPT.

References

[1] http://www.awea.org/newsroom/pressreleases/release_01-24-11.cfm; 2011 [accessed 28.10.11].
[2] Global wind report – annual market update 2010, http://www.gwec.net/fileadmin/images/Publications/GWEC_annual_market_update_2010_-_2nd_edition_April_2011.pdf; 2011 [accessed 28.10.11].
[3] http://www.gwec.net/fileadmin/documents/Publications/GWEC_PRstats_02-02-2011_final.pdf.
[4] MNRE wind power potential in India, http://mnre.gov.in/wpp.htm; 2011 [accessed 28.10.11].
[5] http://www.cwet.tn.nic.in/html/information_yw.html; 2011 [accessed 28.10.11].
[6] Indian Wind Turbine Manufacturers Association, Indian wind energy and economy, http://www.indianwindpower.com/iw_energy_economy.php; 2011 [accessed 28.10.11].
[7] Ministry of new and renewable energy, http://www.mnre.gov.in/.
[8] http://pib.nic.in/newsite/erelease.aspx?relid=39899; 2011 [accessed 29.10.11].
[9] www.eai.in/ref/eve/wind_power_value_chain.pdf; 2011 [accessed 29.10.11].
[10] www.projectstoday.com; 2011 [accessed 21.03.11].
[11] http://www.mnre.gov.in/achievements.htm; 2011 [accessed 29.10.11].
[12] Ministry of Power, http://cea.nic.in/planning/Capacity%20addition%20target%20during%2011th%20plan%20set%20by%20Planning%20Commission%20(Revised)-summary%20region%20wise.pdf; June 2009.
[13] http://www.indianwindpower.com/iw_energy_economy.php; 2011 [accessed 29.10.11].
[14] http://www.inwea.org/aboutwindenergy.html; 2011 [accessed 29.10.11].
[15] http://www.eai.in/ref/ae/win/win.html; 2011 [accessed 29.10.11].
[16] http://www.gwec.net/index.php?id=158; 2011 [accessed 31.10.11].
[17] http://www.mnre.gov.in/gbi/V%20P%20Raja.pdf; 2011 [accessed 31.10.11].
[18] http://www.mnre.gov.in/annualreport/2009-10EN/Chapter%206/chapter%206_1.htm; 2011 [accessed 31.10.11].
[19] http://www.thewindpower.net/country-datasheet-windfarms-5-india.php; 2011 [accessed 21.03.11].
[20] http://www.karnataka.com/industry/power; 2011 [accessed 21.03.11].
[21] http://www.acciona-energia.com; 2011 [accessed 21.03.11].
[22] http://www.windpowerindia.com/index.php?option=com_content&view=article&id=6&Itemid=32; 2011 [accessed 21.03.11].
[23] http://www.azocleantech.com/Details.asp?newsID=11902; 2011 [accessed 21.03.11].
[24] http://www.nedcap.gov.in/Wind_Energy.aspx?ID=29; 2011 [accessed 21.03.11].
[25] http://cdm.unfccc.int/Projects/DB/BVQI1179381212.68/view; 2011 [accessed 21.03.11].
[26] http://anert.gov.in; 2011 [accessed 21.03.11].
[27] http://www.ramakkalmedu.com/wind.html; 2011 [accessed 21.03.11].
[28] http://wbpower.nic.in/wbreda.htm; 2011 [accessed 21.03.11].
[29] http://www.windfair.net/press/2398.html; 2011 [accessed 21.03.11].